Overview

Executive Summary

During space missions, proper elimination and containment of waste, including feces, urine, menses, and vomit, as well as related hygiene, are critical considerations when designing habitable volumes and capabilities for the crew. This should also include the periods of time when the crew will be suited for various activities or phases of the mission/flight. The waste management collection system and related products must be capable of collecting and containing maximum values of all forms of human waste.

Due to the close quarters and time spent in both microgravity and partial gravity, body waste and odors can be difficult to contain. Contamination from body waste can enter the body through the nose, mouth, ears, and cuts in the skin, which can cause a variety of illnesses and infections. Additionally, due to the microgravity conditions, unintended free-floating waste can inadvertently (and unknowingly) soil a crew member. Methods to prevent cross-contamination need to be considered during the vehicle design process. These methods can include isolating the body waste system from the personal hygiene areas and the food system, maximizing the distance between the systems and employing appropriate cleaning and filtering techniques. The trash volume will need to consider the stowage of the body waste and associated trash (wipes, feminine hygiene products, etc.) that is not able to be reprocessed for water reclamation or other recycling activities.

Summary of Waste Management Standards

V2 3006 Human-Centered Task Analysis
V2 6061 Cross-Contamination
V2 7016 Personal Hygiene Capability
V2 7017 Body Cleansing Privacy
V2 7020 Body Waste Management Capability
V2 7021 Body Waste Management System Location
V2 7022 Body Waste Management Privacy
V2 7023 Body Waste Management Provision
V2 7024 Body Waste Accommodation
V2 7025 Body Waste Containment
V2 7026 Body Waste Odor
V2 7027 Body Waste Trash Receptacle Accessibility
V2 7028 Private Body Inspection Accommodation
V2 7029 Body Waste Management Maintenance
V2 7030 Average Feces per Day
V2 7031 Maximum Feces per Event
V2 7032 Average Diarrhea per Day
V2 7033 Maximum Diarrhea per Event
V2 7034 Urine Capacity
V2 7035 Urine per Crewmember
V2 7036 Urine Rate
V2 7037 Vomitus per Collection and Containment
V2 7047 Biological Waste Containment and Disposal
V2 7064 Trash Accommodation
V2 7065 Trash Volume Allocation
V2 7067 Trash Odor Control
V2 7068 Trash Contamination Control
V2 7083 Cleaning Materials
V2 7085 Fecal and Urine Elimination Concurrence
V2 10003 Crew Interface Efficiency
V2 11013 Suited Body Waste Management – Provision
V2 11014 EVA Suit Urine Collection
V2 11015 Suit Urine Collection per Day – Contingency
V2 11016 Suit Feces Collection per Day – Contingency
V2 11017 Suit Isolation of Vomitus

Overview

Previous concerns from crew include:

- Odor control is important and will affect a crewmember's appetite due to the strong smells following a bowel movement.
- Contamination from the Waste Management System (WMS) is difficult to mitigate when the food system is only 1-foot away.
- Maximum Absorbency Garments (MAGs) should not be required to be worn consecutively for long durations due to skin irritations.
- Defecation could take ~45 minutes in microgravity.
- The fecal bag "doesn't stick to your butt well", so escapees happen and was described as "a complete mess."
- The Urine Collection Device (UCD) was uncomfortable and frequently leaked. There was some irritation when used.
- The backpressure of the urine bag contributed to in-flight UTIs.
- Crew was very concerned about voiding ability during time-critical OPS the amount of time it took to get set-up for a voiding dump.

Risks from Body Waste and Hygiene Contamination

In-mission risk

- Cross contamination with fecal mater and other human waste is a known risk to human health to cause medical events that can be deleterious to the crews health and productivity (see medical event below).
- Due to limitations of resources available and distance from Earth, treatment of unexpected medical events can lead loss of mission.

Possible medical events associated with contamination from body waste or use of body waste system

- Gastrointestinal Distress (including gas, bloating, diarrhea, abdominal pain)
- Urinary Tract Infections (UTIs)
- Skin rashes
- Infection
- Eye Irritation

Mission Duration

Shorter missions generally require less extensive personal hygiene facilities. Additional guidelines for determining facility needs are discussed in the section, Architectural Considerations of the HIDH. For safety and health reasons, hygiene facilities must be designed to accommodate partial-body or full-body cleansing before and/or after these functions:

- Urination and defecation
- Exercise
- Medical activities
- Experimentation or other work requiring specialized washing
- Meal consumption
- Accidental exposure to toxic substances
- Eye contamination

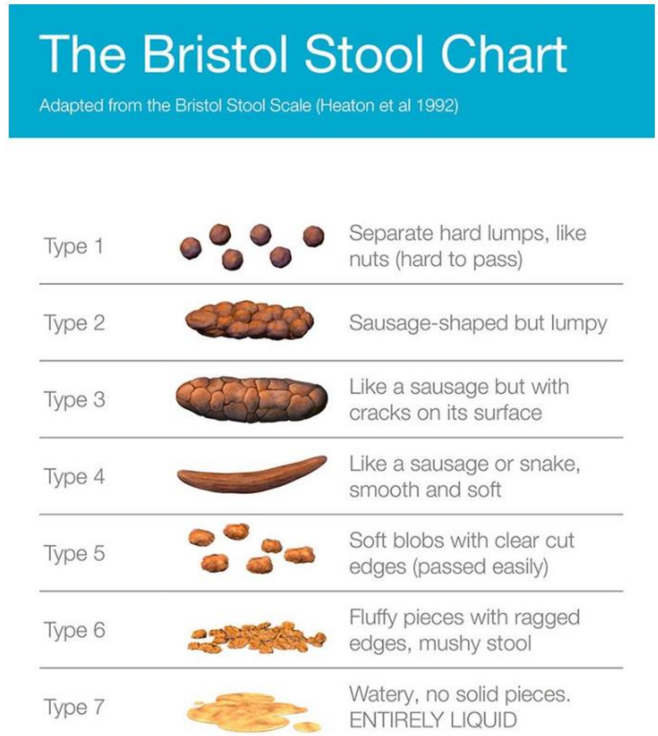
Reference Information

Feces:

- Fecal mass values are for the biological material only.
- Fecal collection and containment includes both the biological material and all hygiene products required for immediate body cleaning after defecation, but mass/volume quantities are limited to the body output only
- The body will generate the same quantity of fecal material based on the food consumption and an individual's metabolism. The variables are the evacuation **frequency** and **water content**.
- The collection capacity requirements account for the **average healthy adult stool output/day (150 g/defecation at a rate of twice per day)**. The number of defecations per day is individually variable ranging from 2/week to 5/day, with the assumed average of 2/day.

Diarrhea:

- Diarrheal events are assumed to be **in place of** normal fecal elimination with the increased quantity based on increased water content and minor amounts of intestinal cellular material.
- The 1.5 L of diarrhea is based on most likely maximal discharge in afflicted individuals. A crewmember could experience up to 8 diarrhea events (average volume of 0.5 L each) per day for up to 2 days, which must be accommodated.



Note: Waste collection should accommodate all variations of stool, however "normal" feces is typically types 3-4.

An artificial gravity study at the University of Texas Medical Branch and a Tufts University bed rest study studied the fecal weights of 32 subjects who consumed meals with a nutritional equivalent to that of current spaceflight meals. These studies resulted in an **average** of **137.69** grams/event with a **maximum** event of **504.21** grams.(Smith et al.)

References

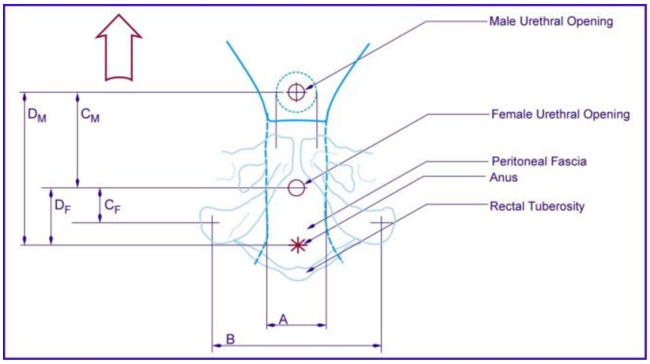
- Apollo Medical Summit
- Apollo Flight Journal. https://history.nasa.gov/afj/
- Apollo Program Summary Report. https://www.hq.nasa.gov/alsj/alsj-JSC09423.html
- Human Integration Design Handbook, Revision 1. Section 7.4 Body Waste Management.
- *Quantification of menstrual blood loss.* The Menorrhagia Research Group. The Obstetrician & Gynaecologist. 6:88-92, 2004.
- Smith, Scott M., principal investigator, 2006, Artificial Gravity Study, University of Texas Medical Branch

Reference Information

Urine: The waste management system must be capable of collecting and containing a maximum total urine output volume of: $V_u = 3 + 2t$ liters per crewmember, where t is the mission length in days. Urine production on the first day after launch is 3 liters per crewmember. Urine output may be slightly greater or less in different phases of the mission (associated with g-transitions) and with different fluid intake levels. The average void will vary from 100 to 500 mL. Rarely, a single void might be as much as 1 liter, so the equipment must be able to accommodate this maximum.

The capability must exist to collect 1 liter of urine per crewmember per hour. The rate of urinary delivery into the system from the body will vary by gender (greater for females because of lower urethral resistance) but averages 10 to 35 mL/s. Maximum flow rate with abdominal straining in a female may be as high as 50 mL/s for a few seconds, and must be accommodated. The number of urinations per day is individually variable, with an average of six times per day, which must be accommodated.

Note: Urine output may be slightly greater or less in different phases of the mission (associated with g-transitions) and with different fluid intake levels.



Anatomical Measurements for Body Waste Management Design

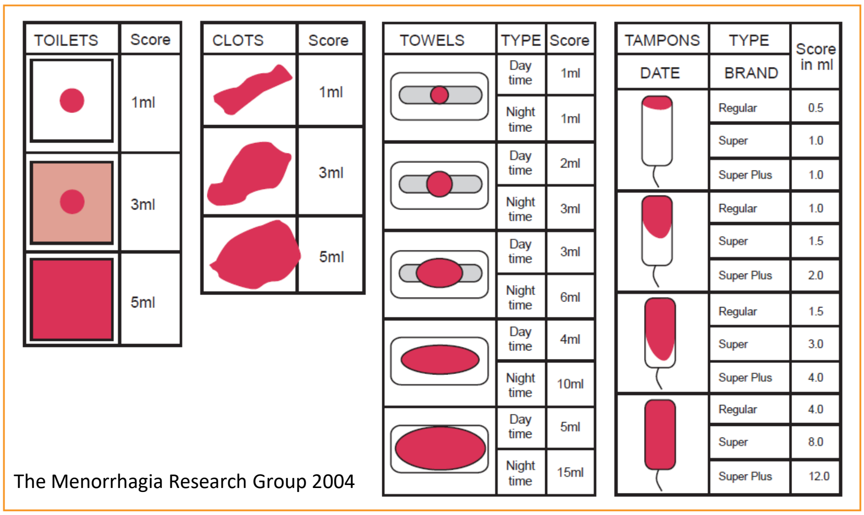
Anatomy	Description	Dimension Range (cm)	
		Male	Female
A	Lateral separation of ischial tuberosity	10-14	11-16
B	Width of perineal furrow	7.5-9	7.5-9
C	Anterior and posterior separation between tuberosities and exterior urethral opening	13-27	6-9
D	Anterior and posterior separation between anus and external urethral opening	15-30.5	9-11.5

Vomitus: Space Adaptation Syndrome (SAS) occurs in up to 70% of first time fliers (30% of whom may experience vomiting) during the first 48 to 72 hours of microgravity. In addition, a possible water landing may cause crewmembers to succumb to sea sickness. The average number of vomiting episodes per crewmember will vary from 1 to 6 per day, over a 2- to 3-day period.

The waste management system must be capable of collecting and containing vomitus for up to 8 events of an average of 500 mL each. The maximum volume of expelled vomitus can be 1 L of solids and fluids, with a fully distended stomach. The average volume of vomitus is more likely to be 200 to 500 mL.

Reference Information

Menses: Approximately once every 26 to 34 days and lasting 4 to 6 days, approximately 80% released during first 3 days. The capability must exist to collect and contain 113.4 grams per female crewmember per cycle.



ISS Waste Management System

Summary of Waste Standards

Waste Type	Average Per Event	Maximum Per Event	Duration/Frequency
Feces[a]	Volume: 150 mL (5 fl. oz.) Mass: 150 g (0.13 lb)	Volume: 500 mL (16.9 fl. oz.) Mass: 500 g (1.1 lb) Length: 33.0 cm (13.0 in)	Average of two events per day
Diarrhea[b]	Volume: 500 mL (16.9 fl. oz.) Mass: 500 g	Volume: 1500 mL (50.7 fl. oz.) Mass: 1500 g	Eight events per day for up to two days
Urine[c]	Volume: 100-500 mL (3.4-16.9 fl. oz.) Flow Rate: 10-35 mL/s (0.34-1.2 fl. oz./s) Mass: 100.7-513.8 g (0.2-1.1 lb)	Volume: 1000 mL (33.8 fl. oz.) Flow Rate: 50 mL/s (1.9 fl. oz./s) Mass: 1027.6 g (2.3 lbs)	Average of six events per day
Vomitus	Volume: 500 mL (16.9 fl. oz.) Mass: (Varies dependent on stomach contents.)	Volume: 1000 mL (33.8 fl. oz.) Mass: (Varies dependent on stomach contents.)	Eight events per day for up to three days in-flight and post-landing
Menses[d]	Volume: 30-50 mL (1.0-1.7 fl. oz.) Mass: (see footnote)	Volume: 114 mL (3.9 fl. oz.) Mass: (see footnote)	Approx. 80% released within the first 3-4 days

Note: a) Fecal material has a high water content and is assumed to have a specific gravity of 1.0 for purposes of this specification. b) Diarrhea values include for fecal amounts. c) Normal values for urine's specific gravity are between 1.002 and 1.028 which means that normally, a gallon of urine weighs between 8.362 and 8.579 pounds, or slightly more than water. d) Menses mass considerations will need to accommodate for the method of collection, i.e. pads and tampons.

Application

Design Guidance and Factors to Consider

- Protect crew from cross-contamination
  - Isolation of contaminant-generating functions (e.g., body waste, trash) is preferred
  - Physical separation of contaminant-sensitive functions (e.g., food prep and consumption) is alternative
  - Provide adequate and appropriate provisions for cleaning and decontamination

- Control odor through ventilation and/or adequate containment

- Control microbial growth by using non-porous surfaces and providing appropriate and adequate cleaning provisions ([V2 6056] **Surface Cleanability**, [V2 7081] **Surface Material Selection**, [V2 7082] **Surface Material Cleaning**, [V2 7083] **Cleaning Materials**)

- Involve the intended user in development and testing for their input on usability in the operating environment
  - Impact of the lack of gravity during tasks
  - Body waste handling and personal hygiene for male and female crew

- Perform analysis to determine total waste expected for the mission and design for stowage and disposal

Note: See back-up slide Application Considers for additional questions to consider when designing waste management systems.

Example daily collection and containment requirements during possible scenarios:

1) Three Healthy crewmembers for both Feces and Urine:

Feces

Average per day: 150 g x 3 crewmembers x 2 defecations = **900 g avg/day**

Maximum per day: 500 g x 3 crewmembers x 2 defecations = **3000 g max/day**

Urine

Average per day: 320 mL x 3 crewmembers x 7 events = **6.7 L avg/day**

Maximum (assumption of only one max event): (1 L x 3 crewmembers) + (320 ml x 6 events x 3 crew) = **8.8 L max/day**

2) Two Healthy crewmembers for Feces and One crewmember afflicted with Diarrhea:

Feces

Average per day: 150 g x 2 crewmembers x 2 defecations = 6**00 g avg/day**

Maximum per day: 500 g x 2 crewmembers x 2 defecations = **2000 g max/day**

Diarrhea (value includes feces and expected higher water content)

Average per day: 500 mL x 1 crewmember x 8 events = **4.0 L avg/day**

Maximum: 1500 mL x 1 crewmember x 8 events = **12 L max/day**

Calculations use the sample values in table noted for average urine quantities and occurrences. The urine max, fecal and diarrhea amounts use values found in NASA-STD-3001.

Sample Urine Quantities Per Crewmember

Metric (Average)	Qty
Events per day	~7
Maximum events per day	~9
Minimum events per day	~6.5
Volume (mL)	320
Maximum volume (mL)	430
Minimum volume (mL)	250

Note: Sample values from various crewmembers on ISS.

Back-Up

Application Considerations

Design and Operations Questions

- Where is the waste management located in relation to the personal hygiene, sleeping quarters, food system, etc?
  - Odors from body waste are expected to occur and are not desirable for the crew.
  - Contamination from the body waste system into the rest of the vehicle must be prevented
  - Is the location of the body waste system in close proximity to the food prep and consumption areas?
  - Are the crew and the food protected from microbial contaminants during the waste management processes?
  - Are the locations of the body waste facilities, personal hygiene, food preparation and trash area in close proximity to each other? Are they positioned in such a way to risk cross-contamination? Are they likely to be used simultaneously to risk cross-contamination?
- Is there adequate space for the expected output of waste and materials used during the collection process?
- Is the trash expected to be handled/transferred within another vehicle? Other crew? Or “dumped”?
- How will the trash management system minimize microbial growth or the spread of microorganisms?
- How will the odors from elimination and trash stowage be controlled?
  - Will the crew be able to smell any of the trash stowed?
  - The crew have noted previously that the smell from the waste management system and body waste have been an issue during food consumption times leading to loss of appetite and not enough caloric intake as required.
- How much “involvement” from the crew is needed to control the waste? (Do they have to “mix” their waste with product to neutralize?)
  - The use of fecal bags previously required that the crew use a finger slot to remove feces from the body and then mix within the bag to neutralize. However, this was not desirable by the crew.
- What kind of medical equipment will be expected to be used? How will the medical waste and biological waste be contained?
  - Does the waste management system have the capability to contain sharp items and the associated biological waste?
  - What kind of biological hazards are expected to be stored?
  - How are biological hazards being stored? Is this storage in proximity to the food storage and prep areas? Or the personal hygiene and body waste areas?
- Can the crew immediately dispose of body waste and associated products after use?
  - The crew will need to be able immediately and easily dispose of body waste and product avoid contamination of the vehicle and other common areas.
  - How are the crew collecting their waste (vomit, diarrhea, feces, urine and menses)?
- Are the body waste management supplies within reach of the crew member during use?
- Will they be able to immediately clean themselves or the area in case there is waste that is not properly contained or “escapes”?
- How will “splashing” be prevented?
- Will the crew be able to inspect their body to ensure they are clean of body waste due to difficulties in partial and microgravity, especially when waste is not contained properly?
- How will the crew be able to have a level of privacy from the other crew (ex. curtain) during self-inspection, as well as during defection, urination or feminine hygiene activities?
- How will the system be cleaned and sanitize?
  - Can the cleaning materials be used effectively, but not cause any unwanted effects to the crew or systems?
  - Are the materials safe in the areas where food is consumed?
  - Compatible with the air/water systems?
  - Do the products leave unwanted or undesirable residues that could hinder or harm crew?
- Is daily or regular preventative maintenance required? If so, how long will this task take?

Referenced Standards

- [V2 3006] Each human spaceflight program or project shall perform a task analysis to support hardware and operations design.

  [Rationale: A detailed task analysis of crew required activities is required to determine appropriate human spacecraft designs and layout along with the appropriate operational activities. This task analysis is utilized by numerous other standards such as net habitable volume, cognitive workload, situational awareness, display design, information management, EVA suit mobility, etc.]

- [V2 6056] System interior surfaces **shall** be compatible for cleaning of microbial contamination to a level of 10,000 CFU per 100 cm^2 or fewer bacteria and to a level of 100 CFU per 100 cm^2 or fewer fungi.

  [Rationale: These limits are intended to ensure that bacterial and fungal contamination on spacecraft internal surfaces can be removed to mitigate the risk of such contamination to the crew. These limits have been documented in SSP 50260. Internal surfaces can become dirtied during normal day-to-day use. This requirement ensures that the dirtied surface is capable of being cleaned, thus precluding an unsafe or unhealthy condition.]

- [V2 6061] The system **shall** control cross-contamination among crew, payloads, e.g., animals and plants, surface vehicles, and planetary environments to acceptable levels in accordance with JPR-1800.5.

  [Rationale: Contamination from payloads and planetary environments to crewmembers can negatively affect crew health; contamination from crewmembers and planetary environments to payloads can affect scientific data; contamination from crewmembers and payloads to planetary environments may impact the health of the planetary environment, including possible microscopic life forms on the surface.]

- [V2 7016] The system **shall** provide the capability for oral hygiene, personal grooming, and body cleansing.

  [Rationale: Oral hygiene and personal grooming activities are to be accommodated by the system through provision of adequate and comfortable bathing and body waste management facilities as these enhance self-image, improve morale, and increase productivity of the crewmember.]

- [V2 7017] The system **shall** provide for privacy during body cleansing.

  [Rationale: Certain hygiene functions are to have a degree of privacy, especially in a vehicle in which other crewmembers may be performing other functions simultaneously. Privacy provides for the psychological well-being of the crew and is to be provided for whole-body and partial body cleaning and donning and doffing of clothing.]

- [V2 7020] The system **shall** provide the capability for collection, containment, and disposal of body waste.

  [Rationale: A body waste management system facilitates the clean, efficient, and reliable collection and management of human waste (urine, feces, vomitus, and menses) and associated equipment and supplies.]

- [V2 7021] The body waste management system **shall** be isolated from the food preparation and consumption areas for aesthetic and hygienic purposes.

  [Rationale: Contamination can occur from a number of sources, including proximity to cross-contamination and the growth of microorganisms. It is critical for crew physical and psychological health that any interference between body waste management functions and food preparation and consumption be prevented. Spaceflight lessons learned indicate this has been an issue during Apollo and ISS missions.]

- [V2 7022] The system **shall** provide privacy during use of the body waste management system.

  [Rationale: Certain hygiene functions are to have a degree of privacy, especially in a vehicle in which other crewmembers may be performing other functions simultaneously. Privacy provides for the psychological well-being of the crew and is to be provided for use of the waste management system.]

- [V2 7023] Body waste management supplies **shall** be accessible to and within reach of crewmembers using the waste management system.

  [Rationale: Personal hygiene and body waste management supplies such as tissues and towels may need to be accessed rapidly.]

- [V2 7024] The body waste management system **shall** allow a crewmember to urinate and defecate simultaneously.

  [Rationale: Accidental discharge of one or both waste components into the habitable volume is not wanted, and it may be difficult for a human to relax the gastrointestinal control sphincter without relaxing the urinary voluntary control sphincter and vice versa.]

- [V2 7025] The system **shall** prevent the release of body waste from the waste management system.

  [Rationale: A release of waste into the closed environment of a spacecraft can contaminate the human and risk the initiation or spread of disease but also can contaminate surfaces, materials, and consumables.]

Referenced Standards

- [V2 7026] The system **shall** provide odor control for the waste management system.

  [Rationale: Uncontrolled waste-associated odors can have an adverse effect on crew performance and can exacerbate pre-existing symptoms of space motion sickness.]

- [V2 7027] Body waste management trash collection **shall** be accessible to and within reach of crewmembers using the waste management system.

  [Rationale: Waste management items that cannot be collected and contained with human waste are to be disposed of immediately after use. Waste management trash collection items are to be within reach of the crewmember so that it is not necessary to egress the waste management restraint system or to access closed compartments.]

- [V2 7028] The body waste management system **shall** provide a means and sufficient volume for crewmembers to perform private bodily self-inspection and cleaning after urination and defecation.

  [Rationale: In microgravity, body waste can float; therefore, after waste management, it is important for crewmembers to verify that they are clean.]

- [V2 7029] All body waste management facilities and equipment **shall** be capable of being cleaned, sanitized, and maintained.

  [Rationale: To remain hygienic, body waste management equipment is to be easily cleaned, sanitized, and maintained. Cleaning and sanitizing helps control odor and microbial growth. As part of the overall maintenance of the hygiene facilities, crewmembers are to have readily accessible trash collection for disposable personal hygiene supplies to minimize crew exposure to the used items.]

- [V2 7030] The human body waste management system **shall** be capable of collecting and containing an average of 150 g (0.3 lb) and 150 ml (5 oz) of solid fecal matter per crewmember per defecation at an average of two defecations per day.

  [Rationale: Fecal waste collection is to be performed in a manner that minimizes possible escape of fecal contents into the habitable vehicle during microgravity operations because of the high content of bacteria contained in the stool. In addition, there is the potential of injury to crewmembers and hardware that could result from such dissemination. The collection capacity accounts for the average healthy adult stool output/day. The number of defecations per day is individually variable ranging from two times per week to five times per day, with the assumed average of two times per day. Solid fecal matter is the description for fecal material that is eliminated as discrete boli and will have surface characteristics that range from relatively dry to sticky depending on the internal water content.]

- [V2 7031] The nominal human body waste management system **shall** be capable of collecting and containing a maximum of 500 g (1.1 lb) and 500 ml (16.9 oz) of fecal matter per crewmember in a single defecation.

  [Rationale: Fecal waste collection is to be performed in a manner that minimizes possible escape of fecal contents into the habitable vehicle during microgravity operations because of the high content of bacteria contained in the stool and because of the potential of injury to crewmembers and hardware that could result from such dissemination. The collection capacity accounts for the healthy adult maximum output during a single event. When a maximum fecal event will occur is unknown, so the human body waste management system must always (nominally) be capable of collecting it.]

- [V2 7032] The nominal human body waste management system **shall** be capable of collecting and containing eight diarrheal events (average volume of 500 ml (16.9 oz) per crewmember per day for up to 2 days.

  [Rationale: The fecal discharge related to gastrointestinal illness (diarrhea) occurs at an increased frequency but is also variable and unpredictable. The total collection volume is to accommodate diarrhea caused by likely pathogens such as rotavirus and enterotoxigenic *E. coli*. When a diarrhea event will occur is unknown, so the body waste management system may process the collection differently, e.g., no compaction. Diarrhea is the description for fecal material that has a sufficiently high water content to not form discrete boli.]

Referenced Standards

- [V2 7033] The nominal human body waste management system **shall** be capable of collecting and containing a maximum diarrhea volume of 1.5 L (0.4 gal) of diarrhea in a single event.

  [Rationale: Fecal waste collection is to be performed in a manner that minimizes possible escape of fecal contents into the habitable vehicle during microgravity operations because of the high content of possibly pathogenic bacteria contained in the stool and because of the potential of injury to crewmembers and hardware that could result from such dissemination. The fecal discharge related to gastrointestinal illness (diarrhea) occurs at an increased frequency and volume but is also variable and unpredictable. The volume for a single discharge is to accommodate diarrhea caused by likely pathogens such as rotavirus and enterotoxigenic E coli. The volume 1.5 L (0.4 gal) is based on evaluation of individuals afflicted with pathogenic diarrhea, as found in medical literature, based on most likely maximal discharge in afflicted individuals. The volume 1.5 L (0.4 gal) is a maximum output, and the average output will be 0.5 L (0.13 gal). When a maximum diarrhea event will occur is unknown, so the body waste management system must always (nominally) be capable of collecting it. The body waste management system may process the collection differently, e.g., no compaction.]

- [V2 7034] The human body waste management system **shall** be capable of collecting 1 L (33.8 oz) of urine per event with up to six urination events per crewmember per day.

  [Rationale: Rarely, a single void might be as much as 1 L (33.8 oz), so the equipment is to be able to accommodate this maximum. The rate of urinary delivery into the system from the body will vary by gender (greater for females because of lower urethral resistance) but averages 10 to 35 ml/s (0.34 to 1.2 oz/s). Maximum flow rate with abdominal straining in a female may be as high as 50 ml/s (1.9 oz/s) for a few seconds.]

- [V2 7035] The human body waste management system **shall** be capable of collecting and containing a maximum total urine output volume of $V_u = 3 + 2t$ liters per crewmember, where t is the mission length in days.

  [Rationale: Urine production on the first day after launch, i.e., flight day 0, is 3 L (0.8 gal) per crewmember. Urine output may be slightly greater or lower in various phases of the mission associated with gravity transitions and fluid intake levels. The urinary collection system is to be capable of collecting all of the crewmember's output in succession, with an average void varying from 100 to 500 ml (3.4 to 16.9 oz). Rarely, a single void might be as much as 1 L (33.8 oz), so the equipment is to be able to accommodate this maximum. The rate of urinary delivery into the system from the body will vary by gender (greater for females because of lower urethral resistance) but averages 10 to 35 ml/s (0.34 to 1.2 oz/s). Maximum flow rate with abdominal straining in a female may be as high as 50 ml/s (1.9 oz/s) for a few seconds. The voided urine is to be isolated to prevent inadvertent discharge in the cabin that could result in injury to a crewmember's skin or mucous membranes or damage to equipment.]

- [V2 7036] The human body waste management system **shall** be capable of collecting a maximum flow rate as high as 50 ml/s (1.9 oz/s).

  [Rationale: Urine output may be slightly greater or lower in various phases of the mission associated with gravity transitions and fluid intake levels. The urinary collection system is to be capable of collecting all of the crewmember's output in succession, with an average void varying from 100 to 500 ml (3.4 to 16.9 oz). Rarely, a single void might be as much as 1 L (33.8 oz), so the equipment is to be able to accommodate this maximum. The rate of urinary delivery into the system from the body will vary by gender (greater for females because of lower urethral resistance) but averages 10 to 35 ml/s (0.34 to 1.2 oz/s). Maximum flow rate with abdominal straining in a female may be as high as 50 ml/s (1.9 oz/s) for a few seconds. The voided urine is to be isolated to prevent inadvertent discharge in the cabin that could result in injury to a crewmember's skin or mucous membranes or damage to equipment.]

- [V2 7037] The human body waste management system **shall** be capable of collecting and containing vomitus for up to eight events of an average of 500 ml (16.9 oz) in a single event.

  [Rationale: Vomiting and its associated odor, mainly produced by the compound putrescence, may trigger a bystander nausea and vomiting reaction in adjacent crewmembers located in close proximity in an enclosed space. Space Adaptation Syndrome (SAS) occurs in up to 70% of first time fliers (30% of whom may experience vomiting) during the first 48 to 72 hours of microgravity. In addition, a possible water landing may cause crewmembers to succumb to sea sickness. The average number of vomiting episodes per crewmember will vary from 1 to 6 per day, over a 2- to 3-day period. Regurgitation of the entire stomach contents results on average in 0.2 to 0.5 L (6.8 to 16.9 oz) of vomitus per event. Stowage and disposal is to be adequate for a worst-case number of involved crew, severity and duration of symptoms, as well as volume of gastrointestinal contents regurgitated.]

- [V2 7047] Biological hazards, like blood and other bodily fluids, **shall** be contained and safely disposed to minimize contamination of other crewmembers.

  [Rationale: If not properly contained, contents could damage equipment, injure crewmembers, and transmit disease. Biological waste, including suited feces/urine collection devices, vomit, and feminine hygiene products, can also cause injury and transmit disease.]

Referenced Standards

- [V2 7064] The system **shall** provide a trash management system to accommodate (stow, neutralize, and dispose) all expected wet and dry trash, including sharp items, harmful chemicals, and biological and radioactive waste.

  [Rationale: If not properly contained, trash contents could damage equipment, injure crewmembers, and transmit disease. Different types of trash require specific types of wrapping and containment. The trash management plan identifies the types of trash to be generated during mission operations; such identification then guides the disposition of the trash. Flight crews as well as ground personnel are expected to manage trash.]

- [V2 7065] Trash stowage volumes shall be defined and allocated for each mission.

  [Rationale: The trash plan defines the types and quantities of trash expected during mission operations. Trash buildup occurs, especially on missions where there is no expendable vehicle to carry away the trash. Dedicated trash stowage volumes and locations are needed and are to be coupled with appropriate packaging and containment.]

- [V2 7067] The trash management system shall provide odor control of trash.

  [Rationale: Uncontrolled odors can have an adverse effect on crew performance and can exacerbate pre-existing symptoms of SAS.]

- [V2 7068] The trash management system shall prevent the release of trash into the habitable environment.

  [Rationale: Many components of trash act as nutrient sources for microorganisms that can quickly increase their concentrations. These microorganisms can include medically significant organisms, which could negatively impact crew health and performance.]

- [V2 7081] The system **shall** be designed with surface materials that do not promote the growth of microorganisms.

  [Rationale: Program requirements are to be established so that unique and non-standard surface materials such as materials that retain moisture or restrict air movement are evaluated for this feature.]

- [V2 7082] The system **shall** contain surface materials that can be easily cleaned and sanitized using planned cleaning methods.

  [Rationale: Program requirements are to be established so that surface materials such as highly textured materials are assessed for this feature.]

- [V2 7083] The system **shall** provide cleaning materials that are effective, safe for human use, and compatible with system water reclamation, air revitalization, and waste management systems.

  [Rationale: Program requirements are to be established so that cleaning materials are assessed for these features. Effective cleaning materials leave a cleaned surface ready for use without the need for additional cleaning. For example, an effective window cleaning material leaves the window with no accumulation, streaking, or any other artifact that could interfere with the use of the window (photography or piloting tasks). On the other hand, cleaning material used on a dining table could be considered effective even with the presence of streaks or accumulation, as long as the surface is safe on which to prepare, serve, and consume food.]

- [V2 7085] The body waste management system **shall** be capable of collecting and containing all waste during simultaneous defecation and urination.

  [Rationale: It is common for individuals to not be able to separate defecation and urination. Body waste collection systems must have sufficient capability to capture and contain both.]

- [V2 10003] The system **shall** provide crew interfaces that are efficient, e.g., with reduced training time, task time, and frustration.

  [Rationale: Efficiency is determined by time on task, number of errors made, and the training demands. Maximizing efficiency should not be achieved through high training demands or performance pressure. Crew interfaces that do not maximize efficiency can result in frustration.]

- [V2 11013] Suits **shall** provide for management of urine, feces, menses, and vomitus of suited crewmembers.

  [Rationale: The total system is to be designed for body waste collection, as well as disposal of waste in the system's waste management system and cleaning of the suit for reuse. Waste management items are to be able to contain and dispose of human waste with as much containment and isolation as possible. Provisions are to be available for personal hygiene and suit cleaning.]

Referenced Standards

- [V2 11014] LEA suits **shall** be capable of collecting a total urine volume of V_u=0.5 + 2t/24 L throughout suited operations, where t is suited duration in hours.

  [Rationale: This requirement allows crewmembers to eliminate liquid waste at their discretion without affecting work efficiency during suited operations. The suit is only responsible for the expected urinary output during the time that the crewmember is in the suit. The urinary collection system is to be capable of collecting all of the crewmember's output in succession, with an average void varying from 100 to 500 ml (3.4 to 16.9 oz). The rate of urinary delivery into the system from the body varies by gender (greater for females because of lower urethral resistance) but averages 10 to 35 ml/s (0.34 to 1.2 oz/s). Maximum flow rate with abdominal straining in a female may be as high as 50 ml/s (1.9 oz/s) for a few seconds. Output collection capacity is designed to match water input potential; the Vu equation does not consider variables such as metabolic rate, relative humidity, or hydration, which could affect total urine volume. The voided urine is to be isolated to prevent inadvertent discharge in the cabin that could result in injury to a crewmember's skin or mucous membranes or damage to equipment.]

- [V2 11015] For contingency suited operations lasting longer than 24 hours, suits **shall** be capable of collecting and containing 1 L (33.8 oz) of urine per crewmember per day.

  [Rationale: Urine output may be slightly greater or lower in various phases of the mission associated with g-transitions and fluid intake levels. Rarely, a single void might be as much as 1 L (33.8 oz), so the equipment is to be able to accommodate this maximum. Also, in the event of an unrecoverable vehicle pressure failure wherein an extended stay in the suit is used to maintain life, crewmembers are to have the capability to access fecal and urine collection systems. The voided urine is to be contained by the stowage and disposal hardware to prevent inadvertent discharge into the suit that could result in injury to the crewmember's mucous membranes or equipment.]

- [V2 11016] During contingency suited operations, suits **shall** be capable of collecting 75 g (0.15 lb) (by mass) and 75 ml (2.5 oz) (by volume) of fecal matter per crewmember per day.

  in the suit is used to maintain life, crewmembers are to have the capability to access fecal and urine collection systems. Fecal waste collection is to be performed in a manner that minimizes escape of fecal contents into the general suit environment during microgravity operations because of the high content of possibly pathogenic bacteria contained in the stool. In addition, there is the potential of injury to crewmembers and hardware that could result from such dissemination. EVA suits are to accommodate for fecal waste collection and containment during all suited activities. Suited activities are nominally not expected to exceed 10 hours. The waste quantities reflect the altered composition of the nutrition supplied during contingency suited operations and are characteristically low in residue.]

- [V2 11017] Suits **shall** provide a means for the isolation of vomitus from the crewmember's face.

  [Rationale: SAS has affected crewmembers in the first 72 hours of flight. The crew is nominally suited during the first 72 hours of flight for certain dynamic phases; vomiting in the suit may occur at these times or if a contingency EVA occurs within that time frame. On the planetary surface, a high magnitude SPE could result in exposures that produce prodromal nausea and vomiting. If vomitus enters the internal suit environment, it should be kept away from the suited crewmember's naso-pharyngeal space. Uncontrolled accumulation of vomitus may also interfere with a crewmember's vision.]